Prepared in cooperation with the
U.S. Bureau of Reclamation

Simulated Water-Management Alternatives Using the Modular Modeling System for the Methow River Basin, Washington

Open-File Report 2004–1051

U.S. Department of the Interior
U.S. Geological Survey

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Simulated Water-Management Alternatives Using the Modular Modeling System for the Methow River Basin, Washington**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Department of the Interior U.S. Geological Survey 1849 C. Street, NW Washington, DC 20240**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**20**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Simulated Water-Management Alternatives Using the Modular Modeling System for the Methow River Basin, Washington

By Christopher P. Konrad

Prepared in cooperation with the
U.S. Bureau of Reclamation

Open-File Report 2004-1051

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Geological Survey, Reston, Virginia: 2004
For sale by U.S. Geological Survey, Information Services
Box 25286, Denver Federal Center
Denver, CO 80225-0286

For more information about the USGS and its products:
Telephone: 1-888-ASK-USGS
World Wide Web: http://www.usgs.gov/

Suggested citation:
Konrad, C.P., 2004, Simulated water-management alternatives using the Modular Modeling System for the Methow River Basin, Washington: U.S. Geological Survey Open-File Report 2004–1051, 12 p.

Contents

Figures

Tables

Simulated Water-Management Alternatives Using the Modular Modeling System for the Methow River Basin, Washington

By Christopher P. Konrad

Abstract

A precipitation-runoff model for the Methow River Basin was used to simulate six alternatives: (1) baseline of current flow, (2) line irrigation canals to limit seepage losses, (3) increase surface-water diversions through unlined canals for aquifer recharge, (4) convert from surface-water to ground-water resources to supply water for irrigation, and (5) reduce tree density in forested headwater catchments, and (6) natural flow. Daily streamflow from October 1, 1959, to September 30, 2001 (water years 1960–2001) was simulated. Lining irrigation canals (alternative 2) increased flows in the Chewuch, Twisp, and the Methow (upstream and at Twisp) Rivers during September because of lower diversion rates, but not in the Methow River near Pateros. Increasing diversions for aquifer recharge (alternative 3) increased streamflow from September into January, but reduced streamflow earlier in the summer. Conversion of surface-water diversions to ground-water wells (alternative 4) resulted in the largest increase in September streamflow of any alternative, but also marginally lower January flows (at most -8 percent in the 90-percent exceedence value). Forest-cover reduction (alternative 5) produced large increases in streamflow during high-flow periods in May and June and earlier onset of high flows and small increases in January streamflows. September streamflows were largely unaffected by alternative 5. Natural streamflow (alternative 6) was higher in September and lower in January than the baseline alternative.

Introduction

At the request of the U.S. Bureau of Reclamation, the U.S. Geological Survey (USGS) used a recently developed precipitation-runoff model for the Methow River Basin (Ely, 2003) to assess the effects of different water-management alternatives on streamflow throughout the Methow River Basin (fig. 1). The water-management alternatives represented a range of alternatives that are being considered by the Methow Basin Planning Unit in the development of a watershed plan. The alternatives include possible actions such as lining irrigation canals to limit seepage losses, increasing surface-water diversions through unlined canals for aquifer recharge, converting from surface-water to ground-water resources to supply water for irrigation, and reducing tree density in forested headwater catchments. Streamflow under these alternatives was compared with a simulated baseline representing current conditions and a “natural” flow alternative representing streamflow patterns without surface-water diversions or ground-water pumping, but with the same vegetation as the baseline alternative.

A precipitation-runoff model for the Methow River Basin (fig. 1) was constructed using the USGS Modular Modeling System (MMS) (Leavesley and others, 1996). The model calculates evapotranspiration (ET), subsurface flow, and surface-water runoff from hillslope areas, or hydrologic response units (HRU), on the basis of daily records of precipitation and air temperature, with values distributed across the basin as described by Ely (2003). MMS routes the runoff through a channel network represented by a series of nodes. The Methow River Basin was divided into 620 HRUs. Vegetation and soil parameters were assigned using automated algorithms in the GIS Weasel (Viger and others, 1998). The model represented 16 surface-water diversions to irrigation canals, canal seepage, application of water to agricultural fields, and ET and infiltration of applied water. Surface-water diversions were subtracted from streamflow at the node (a point along a river) specified for each diversion. Where the specified diversion rate is greater than streamflow at the node of diversion, the model limits the diversions to the streamflow available at the node. Seepage from irrigation canals was allocated to ground-water reservoirs, which represent the shallow aquifer under a specific area of the valley.

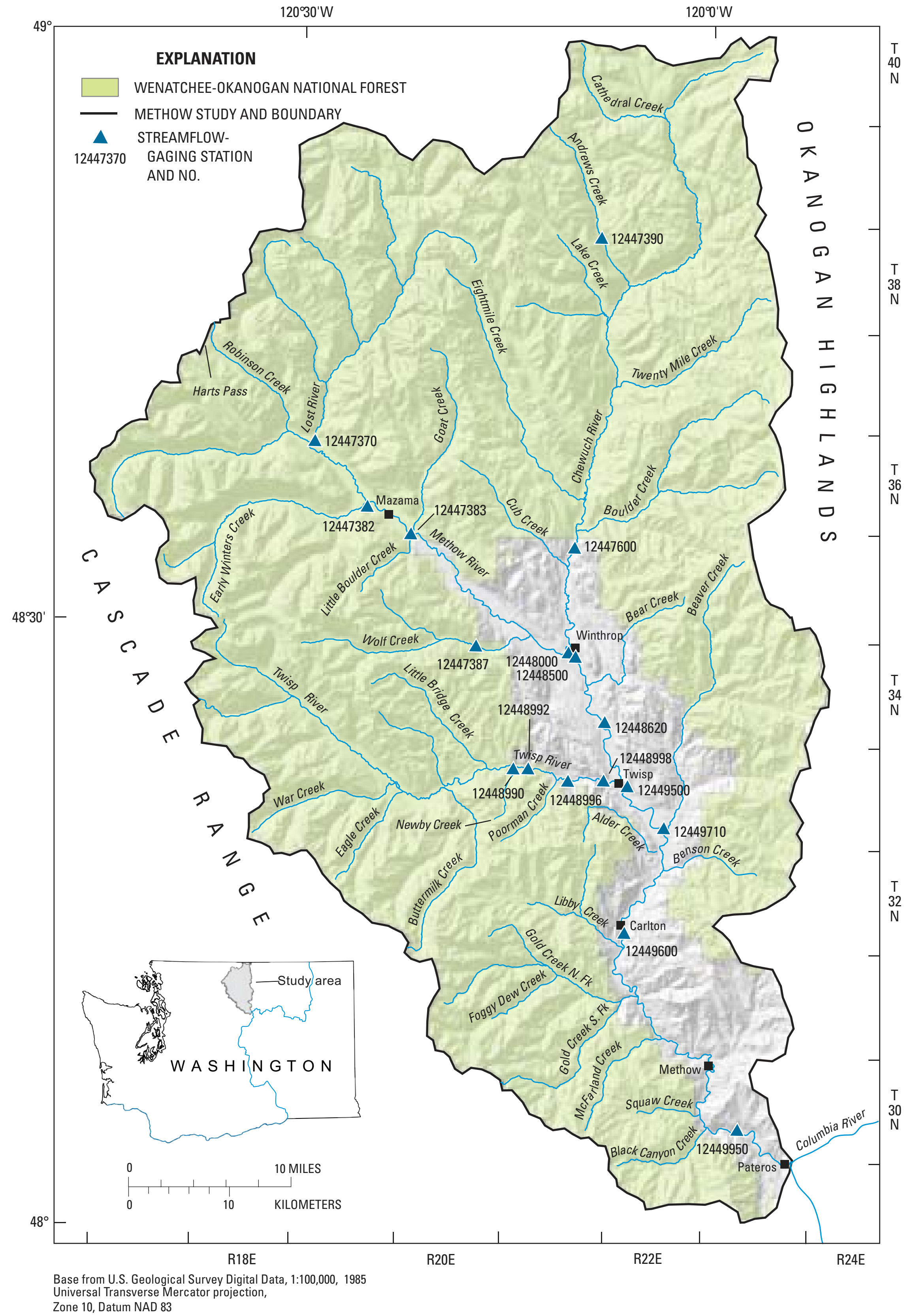


Figure 1. Location of the Methow River Basin and streamflow-gaging stations used in the study of water-management alternatives.

Description of Water-Management Alternatives

Alternative 1. Baseline

This alternative represents current conditions as simulated by Ely (2003). Surface water was diverted from nodes to the 16 canals from May through October at rates that varied during the season (see table 3 in Ely, 2003), but were constant year-to-year. There were no seepage losses from two canals (Wolf Creek and Skyline) for the baseline alternative because they have been replaced by pipes. Seepage losses in the other 14 canals were assumed to be 50 percent of the amount of water diverted to each canal. Requirements for shutting down the Early Winters (T. 36 N., R. 19 E., sec. 26), Willis (T. 36 N., R. 21 E., sec. 27), Skyline (T. 36 N., R. 21 E., sec. 25), and Wolf Creek (T. 34 N., R. 20 E., sec. 2) canals to maintain minimum instream flows (National Marine Fisheries Service, 2000a; 2000b; and 2000c) are not included in the baseline or other alternatives.

Alternative 2. Lined Irrigation Canals

The baseline alternative was modified by eliminating seepage from all canals and reducing the surface-water diversions by 50 percent in the 14 canals that had seepage losses under the baseline alternative. The diversion rates for the Skyline and Wolf Creek canals were the same as those under the baseline alternative because seepage losses are assumed to have been eliminated when large portions of these canals were replaced with pipes.

Alternative 3. Increased Aquifer Recharge by Irrigation-Canal Seepage

The baseline alternative was modified by increasing surface-water diversions by 25 percent, except for Wolf Creek and Skyline, for which diversions were increased 50 percent, and by increasing seepage to 60 percent of diversions for all 16 canals. Diversions during September were not increased above the rates used for the baseline alternative. The additional surface water diverted from rivers and streams under this alternative was allocated to canal seepage. The net effect of the increased rate of diversion and seepage was to increase recharge from irrigation-canal seepage by approximately 50 percent.

Alternative 4. Conversion of Irrigation-Water Supply from Surface-Water to Ground-Water Resources

The baseline alternative was modified by eliminating surface-water diversions and, instead, supplying water to each irrigation system from a ground-water reservoir. Ground-water pumping rates were equal to half of the surface-water diversion rates to account for the elimination of seepage losses in all systems except Wolf Creek and Skyline, for which seepage losses are assumed to have been eliminated when these canals were replaced with pipes. The pumped water was subtracted in MMS from ground-water storage in ground-water reservoirs associated with the HRUs for each irrigation system. At the node where an irrigation system previously (under the baseline alternative) diverted surface water, streamflow was still required to be available before water could be pumped from a ground-water reservoir by an irrigation system. The requirement kept pumping equivalent to diversion during low-flow periods, so that any difference in streamflow between alternatives was a result of the different sources of water and not in the rate of use. The requirement also is consistent with the conversion of an appropriative right from a surface-water source to a ground-water source, which could limit use of ground water to periods when surface water is available at the prior source.

MMS modules provide a simplified representation of ground-water flow hydraulics and ground-water discharge to rivers, and therefore do not represent the hydraulics of ground-water flow over short distances or aquifer recharge by rivers. As a result, this alternative does not address the local effects of ground-water pumping, including streamflow losses resulting from pumping close to a river or stream. Instead, ground-water pumping is represented as the uniform drawdown of the ground water over the area covered by each ground-water reservoir, which is equal to the area of the corresponding HRU.

Two existing MMS modules (listed in *italics*), originally developed by Mastin and Vacarro (2002), were modified for this alternative. Variables and hillslope parameters that are referenced are listed in [CAPITALS]. First, the module *divrt_apply_prms* was modified so that surface-water diversions were not subtracted from streamflow at a node.

Second, the module *gwflow_loss_min_darcy* was modified so that “seepage” [GW_IN_LOSS] was subtracted from inflow to a ground-water reservoir [GWRES_IN(i)] rather than added to it, as was the case for irrigation-canal seepage in the module developed by Mastin and Vacarro. By subtracting GW_IN_LOSS from ground-water storage, GW_IN_LOSS represents the amount of water pumped from the aquifer. The parameter [LOSS_DIV] was set at 100 percent, so the total pumping rate specified in the data file, *.dat.div, for a given canal was subtracted from the ground-water reservoirs that previously had been recharged by that canal. Pumping rates may be higher than surface-water diversions under the baseline because the model dynamically adjusts diversion (or pumping rate, in this case) to the streamflow available at the node of diversion, but pumping does not directly reduce streamflow at a node.

Alternative 5. Forest-Cover Reduction

The baseline alternative was modified to represent the removal of forest canopy and soil removal or compaction that might occur in response to an intense forest fire or timber harvest. Data from the Methow River Basin were not available to calibrate the model for the effects of significant forest-cover reduction. However, five parameters would likely be affected by such changes: the density of forest cover in the summer [COVDEN_SUM] and winter [COVDEN_WIN], the shortwave-radiation transmission coefficient [RAD_TRNCF], the storage capacity of the upper part of the soil column [SOIL_RECHR_MAX], and the total storage capacity of the soil column [SOIL_MOIST_MAX]. Because there is a physical basis for each of these parameters, plausible changes in their values were selected to simulate changes in forest cover (table 1).

The values of the five hillslope parameters (table 1) were modified in 36 HRUs representing the drainage basins for Andrews, Lake, Little Bridge, and Buttermilk Creeks. The Andrews Creek and Lake Creek Basins constitute 12 percent (62 of 525 square miles) of the Chewuch River Basin, and Little Bridge and Buttermilk Creek Basins constitute 24 percent (59 of 245 square miles) of the Twisp River Basin. Combined, the four catchments constitute about 7 percent of the drainage area of the Methow River near Pateros (121 of 1,777 square miles).

Alternative 6. Natural Flow

The baseline alternative was modified by eliminating surface-water diversions. Otherwise, the model parameters and data from the baseline alternative were used for alternative 6.

Table 1. Modular Modeling System parameters modified to represent changes in forest cover

Parameter	Description	Old values	New values
COVDEN_SUM	Fraction of HRU area covered by dominant vegetation in summer	0.482 to 1.0	0.1
COVDEN_WIN	Fraction of HRU area covered by dominant vegetation in winter	0.349 to 1.0	.1
RAD_TRNCF	Fraction of shortwave radiation transmitted through canopy	0.063 to 0.448	.75
SOIL_RECHR_MAX	Upper soil storage capacity, in inches, over HRU area	1.69 to 1.75	.5
SOIL_MOIST_MAX	Total soil storage capacity, in inches, over HRU area	2.99 to 3.46	1.5

Simulations of Water-Management Alternatives

Daily streamflow for the period from October 1, 1959, to September 30, 2001, (water years 1960-2001) was simulated. The results are summarized in terms of simulated annual streamflow at 12 nodes where there are USGS streamflow-gaging stations in the Methow River Basin (table 2). The effects of water-management alternatives on low flows were evaluated in terms of percent difference from the baseline alternative using simulated monthly mean streamflow that was exceeded in 50 and 90 percent of the months of September and January in the simulation period. These months typically have the lowest streamflows of the year and bracket the period when water-management activities are most likely to affect streamflow. In September, streamflow is still used for irrigation but is also critical for incubation of upper Columbia River spring chinook salmon. Maintaining streamflow in January may be critical for salmonid rearing because of ice formation in the rivers during periods of extremely low temperatures. The monthly statistics are provided for all 12 stations (table 3 and table 4). Water management alternatives are not expected to affect high-flow conditions, with the exception of alternative 5, and, consequently, were not analyzed.

Although Ely (2003) showed that simulated streamflow for current conditions was generally unbiased and was accurate to about 10 percent compared with observed monthly mean streamflow in the summer and autumn at most gages during the calibration period (water years 1992 to 2001), simulated daily streamflow is not sufficiently accurate to distinguish between the results of different alternatives. In general, the baseline alternative is biased toward under-predicting flows during low-flow periods in dry years. Because of the error and potential bias in the simulated streamflow, the results from each of the water-management alternatives were evaluated relative to the baseline alternative rather than to observed streamflow. The 10-, 50-, and 90-percent exceedence values for daily streamflow were calculated for the simulation period. The daily results for the Chewuch River at Winthrop, Twisp River near Twisp, and Methow River near Pateros are presented here (fig. 2). The patterns observed at these gages are similar and are generally representative of streamflow patterns at points downstream of surface-water diversions.

Effects of Water-Management Alternatives on Annual Streamflow

Conversion from surface-water to ground-water resources (alternative 4) and forest-cover reduction (alternative 5) produced the largest increase in annual streamflow from the baseline (alternative 1) of any of water-management alternatives (table 2). The effect on streamflow of conversion to ground-water resources was greatest at stations where a relatively large proportion of streamflow currently is diverted for irrigation and the water is conveyed and applied to fields that are downstream or outside of the drainage area of the station. For example, Wolf Creek below the diversion and the Chewuch River at Winthrop had the largest increases in median annual streamflow (50 percent exceedence), 10 and 7 percent respectively, under alternative 4. Streamflow increased under alternative 4 at both these stations because, under the baseline alternative, surface water was diverted and conveyed downstream of these stations. Conversion to ground-water resources had the greatest relative effect on streamflow during low flow years: the 90-percent exceedence value for annual streamflow increased 17 percent in Wolf Creek below the diversion and 14 percent in the Chewuch River at Winthrop. Conversion to ground-water resources also increased annual streamflow in the Methow River near Pateros. The increase was a result of using ground-water storage, although the increase was at most only 6 percent for annual streamflow exceeded 90 percent of the time.

The increase in streamflow from forest-cover reduction (alternative 5) was even greater at stations downstream of areas where forest cover was reduced than under alternative 4, with a 50-percent increase in median annual streamflow in Andrews Creek and a 13-percent increase in median annual streamflow in the Twisp River near Twisp. The increase in streamflow is a result of a decrease in interception and sublimation of snow from trees. As with alternative 4, the largest increase in response to forest-cover reduction was during low-flow years. The 90-percent exceedence value for annual streamflow increased 91 percent in Andrews Creek and 17 percent in the Twisp River near Twisp. Annual streamflow also increased in wet years: the 10-percent exceedence value for annual streamflow increased by 36 percent in Andrews Creek and 14 percent in the Twisp River near Twisp. Peak runoff is likely to be higher and earlier if forest cover is removed than under current conditions (fig. 2). Streamflow for the Twisp River above Newby Creek had the same increases as the Twisp River near Twisp. Streamflow in the Chewuch River above Cub Creek and at Winthrop had increases like Andrews Creek but of smaller percentages of streamflow.

There was no more than a 4-percent difference between alternatives 2 or 3 and the baseline alternative in the 10^{th}, 50^{th}, and 90^{th} percentiles of annual streamflow at the 12 stream-gaging stations. Annual streamflow under alternative 6 was higher at stations downstream of surface-water diversion than streamflow under the baseline alternative.

Table 2. 90-, 50-, and 10-percent exceedence values for simulated annual mean streamflow for water years 1960 to 2001 under six water-management alternatives, and percent difference from baseline alternative

[ft^3/s, cubic feet per second; –, difference from baseline alternative is less than 1 percent]

Streamflow-gaging station and No.	Baseline (alternative 1)	Alternative 2		Alternative 3		Alternative 4		Alternative 5		Unregulated (alternative 6)	
	ft^3/s	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference
90-percent exceedence											
Lost River near Mazama (12447370)	139	139	–	139	–	139	–	139	–	139	–
Twisp River above Newby Creek (12448990)	165	165	–	165	–	165	–	192	17	165	–
Twisp River near Twisp (12448998)	160	163	2	159	–	170	6	187	17	170	6
Methow River above Goat Creek (12447383)	369	369	–	370	–	372	1	369	–	370	--
Methow River at Winthrop (12448500)	582	591	2	583	0	617	6	621	7	609	5
Methow River at Twisp (12449500)	753	765	1	755	0	809	7	831	10	755	0
Early Winters Creek near Mazama (12447382)	101	104	3	100	-1	107	6	101	–	104	3
Methow River near Pateros (12449950)	832	832	–	839	1	879	6	909	9	826	-1
Wolf Creek below diversion near Winthrop (12447387)	18	18	–	17	–	21	17	18	–	21	17
Andrews Creek (12447390)	15	15	–	15	–	15	–	29	91	15	–
Chewuch River above Cub Creek (12447600)	132	133	–	130	-2	138	5	174	31	139	5
Chewuch River at Winthrop (12448000)	146	153	4	147	1	167	14	188	28	162	11
50-percent exceedence											
Lost River near Mazama (12447370)	255	255	–	255	–	255	–	255	–	255	–
Twisp River above Newby Creek (12448990)	283	283	–	283	–	283	–	319	13	283	–
Twisp River near Twisp (12448998)	284	286	1	283	–	294	3	320	13	294	4
Methow River above Goat Creek (12447383)	657	657	–	657	–	660	0	657	–	658	0
Methow River at Winthrop (12448500)	1,143	1,153	1	1,145	0	1,181	3	1,177	3	1,174	3
Methow River at Twisp (12449500)	1,457	1,468	1	1,459	0	1,515	4	1,529	5	1,476	1
Early Winters Creek near Mazama (12447382)	166	169	2	165	-1	172	4	166	–	168	1
Methow River near Pateros (12449950)	1,609	1,609	–	1,616	0	1,659	3	1,681	4	1,620	1
Wolf Creek below diversion near Winthrop (12447387)	35	35	–	34	-4	38	10	35	–	38	10
Andrews Creek (12447390)	29	29	–	29	–	29	–	44	50	29	–
Chewuch River above Cub Creek (12447600)	333	333	–	329	-1	342	3	367	10	342	3
Chewuch River at Winthrop (12448000)	366	372	2	366	–	390	7	405	11	384	5
10-percent exceedence											
Lost River near Mazama (12447370)	335	335	–	335	–	335	–	335	–	335	–
Twisp River above Newby Creek (12448990)	389	389	–	389	–	389	–	434	12	389	–
Twisp River near Twisp (12448998)	397	399	1	396	–	406	2	451	14	407	3
Methow River above Goat Creek (12447383)	879	879	–	879	–	879	–	879	–	878	0
Methow River at Winthrop (12448500)	1,596	1,606	1	1,598	0	1,637	3	1,635	2	1,630	2
Methow River at Twisp (12449500)	2,041	2,052	1	2,043	0	2,102	3	2,126	4	2,069	1
Early Winters Creek near Mazama (12447382)	237	240	1	235	-1	243	3	237	–	238	1
Methow River near Pateros (12449950)	2,315	2,315	–	2,321	0	2,367	2	2,421	5	2,335	1
Wolf Creek below diversion near Winthrop (12447387)	48	48	–	47	-3	52	7	48	–	52	7
Andrews Creek (12447390)	47	47	–	47	–	47	–	63	36	47	–
Chewuch River above Cub Creek (12447600)	562	562	–	558	-1	570	1	605	8	571	2
Chewuch River at Winthrop (12448000)	613	619	1	613	–	636	4	654	7	631	3

Table 3. 90- and 50-percent exceedence values for simulated annual mean streamflow for September water years 1960 to 2001 under six water-management alternatives, and percent difference from baseline alternative

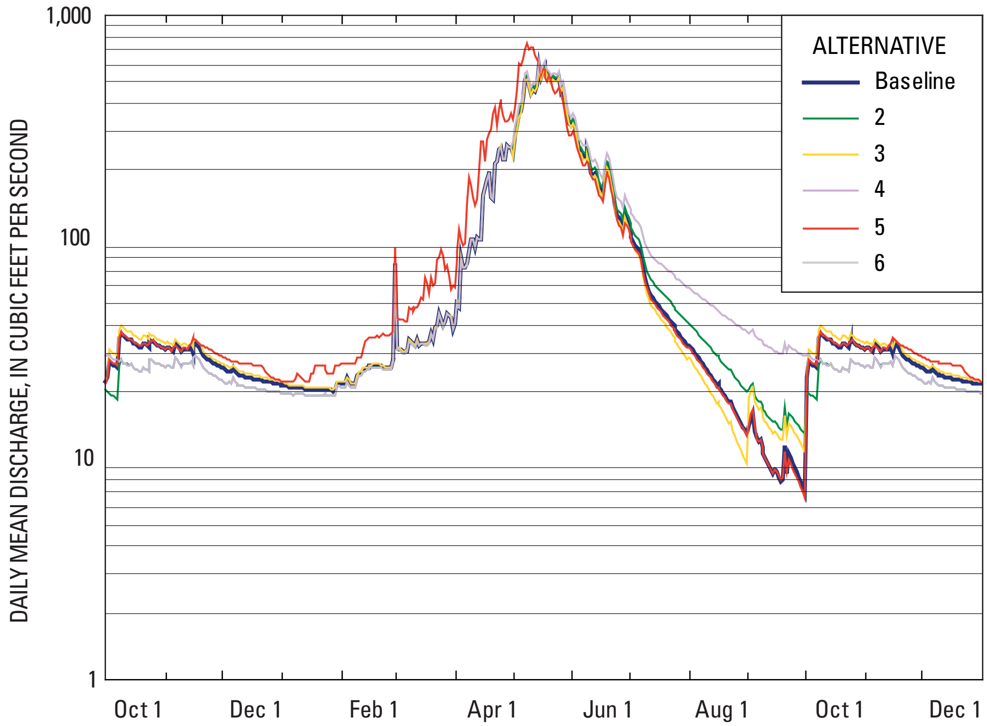
[ft^3/s, cubic feet per second; –, difference from baseline alternative is less than 1 percent; NA, not applicable]

Streamflow-gaging station and No.	Baseline (alternative 1)	Alternative 2		Alternative 3		Alternative 4		Alternative 5		Unregulated (alternative 6)	
	ft^3/s	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference
90-percent exceedence											
Lost River near Mazama (12447370)	28	28	–	28	–	28	–	28	–	28	–
Twisp River above Newby Creek (12448990)	36	36	–	36	–	36	–	36	–	36	–
Twisp River near Twisp (12448998)	15	20	40	19	30	37	152	14	–	37	152
Methow River above Goat Creek (12447383)	89	89	–	90	2	96	8	89	–	94	6
Methow River at Winthrop (12448500)	107	125	17	133	25	180	69	107	–	173	62
Methow River at Twisp (12449500)	100	126	26	129	29	220	119	101	–	181	80
Early Winters Creek near Mazama (12447382)	9	16	77	9	–	22	144	9	–	18	97
Methow River near Pateros (12449950)	141	143	1	177	26	244	73	141	–	200	42
Wolf Creek below diversion near Winthrop (12447387)	0	0	–	0	–	6.3	NA	0	–	6.3	NA
Andrews Creek (12447390)	3.8	3.8	–	3.8	–	3.8	–	4.0	5	3.8	–
Chewuch River above Cub Creek (12447600)	36	38	6	33	-7	53	47	45	25	53	49
Chewuch River at Winthrop (12448000)	18	29	60	33	82	60	228	21	13	55	197
50-percent exceedence											
Lost River near Mazama (12447370)	41	41	–	41	–	41	–	41	–	41	–
Twisp River above Newby Creek (12448990)	54	54	–	54	–	54	–	53	-3	54	–
Twisp River near Twisp (12448998)	34	40	17	38	13	50	48	34	–	56	64
Methow River above Goat Creek (12447383)	136	136	–	138	1	143	5	136	–	140	3
Methow River at Winthrop (12448500)	200	221	10	220	10	265	33	197	-1	275	38
Methow River at Twisp (12449500)	217	243	12	250	15	319	47	212	-2	307	42
Early Winters Creek near Mazama (12447382)	28	35	23	28	–	35	23	28	–	35	25
Methow River near Pateros (12449950)	281	283	1	323	15	389	38	276	-2	352	25
Wolf Creek below diversion near Winthrop (12447387)	2.9	2.9	–	1.3	-55	2.9	–	2.9	–	10.5	260
Andrews Creek (12447390)	5.4	5.4	–	5.4	–	5.4	–	5.2	-4	5.4	–
Chewuch River above Cub Creek (12447600)	78	80	3	76	-3	81	4	76	-2	96	23
Chewuch River at Winthrop (12448000)	56	71	27	70	24	95	69	54	-3	99	77

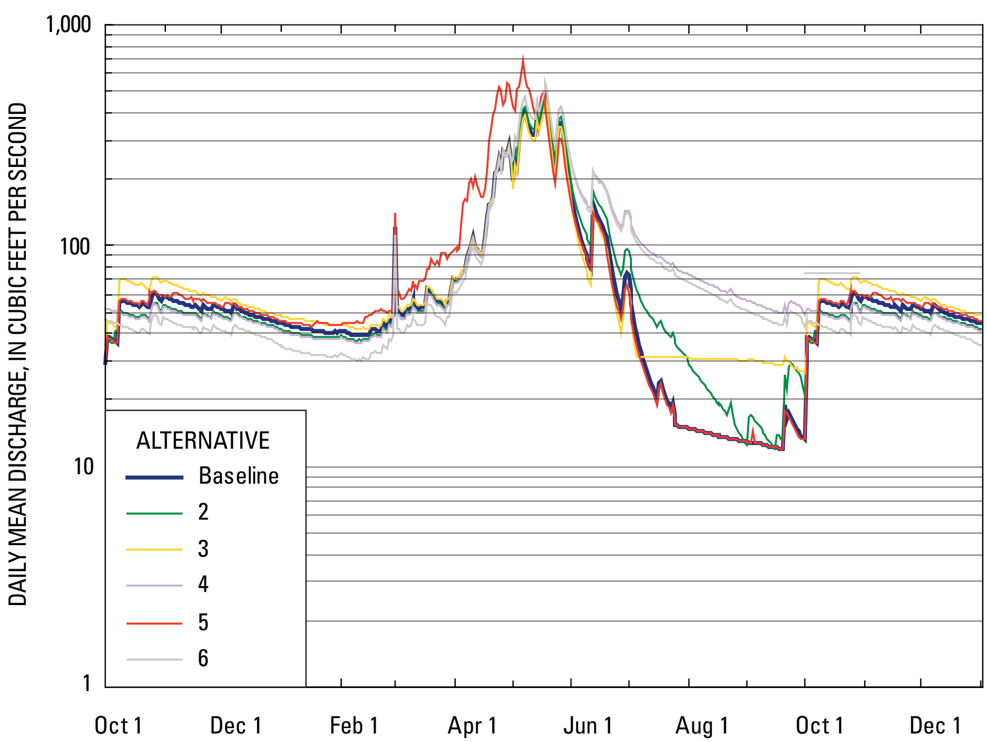
Table 4. 90- and 50-percent exceedence values for simulated monthly mean streamflow for January for water years 1960 to 2001 under six water-management alternatives, and percent difference from baseline alternative

[ft^3/s, cubic feet per second; –, difference from baseline alternative is less than 1 percent]

Streamflow-gaging station and No.	Baseline (alternative 1)	Alternative 2		Alternative 3		Alternative 4		Alternative 5		Unregulated (alternative 6)	
	ft^3/s	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference	ft^3/s	Percent difference
90-percent exceedence											
Lost River near Mazama (12447370)	24	24	–	24	–	24	–	24	–	24	–
Twisp River above Newby Creek (12448990)	20	20	–	20	–	20	–	25	27	20	–
Twisp River near Twisp (12448998)	22	21	-5	22	–	21	-5	26	21	21	-5
Methow River above Goat Creek (12447383)	61	61	–	61	–	61	–	61	–	58	-6
Methow River at Winthrop (12448500)	121	119	-2	126	4	118	-3	123	2	109	-10
Methow River at Twisp (12449500)	150	143	-5	156	4	142	-5	153	2	95	-36
Early Winters Creek near Mazama (12447382)	8	8	–	8	–	8	–	8	–	3	-59
Methow River near Pateros (12449950)	175	166	-5	182	4	165	-6	177	1	129	-26
Wolf Creek below diversion near Winthrop (12447387)	3.3	3.3	–	3.3	–	3.3	–	3.3	–	3.3	–
Andrews Creek (12447390)	2.9	2.9	–	2.9	–	2.9	–	3.6	24	2.9	–
Chewuch River above Cub Creek (12447600)	38	37	-3	39	–	36	-6	41	7	37	-3
Chewuch River at Winthrop (12448000)	44	41	-6	47	9	40	-8	46	6	34	-21
50-percent exceedence											
Lost River near Mazama (12447370)	35	35	–	35	–	35	–	35	–	35	–
Twisp River above Newby Creek (12448990)	47	47	–	47	–	47	–	53	13	47	–
Twisp River near Twisp (12448998)	57	56	–	57	–	56	–	64	13	56	–
Methow River above Goat Creek (12447383)	91	91	–	91	–	91	–	91	–	88	-3
Methow River at Winthrop (12448500)	231	229	-1	235	1	228	-1	235	2	223	-4
Methow River at Twisp (12449500)	328	322	-2	334	2	321	-2	336	2	275	-16
Early Winters Creek near Mazama (12447382)	18	18	–	18	–	18	–	18	–	14	-24
Methow River near Pateros (12449950)	404	395	-2	412	2	394	-3	414	2	369	-9
Wolf Creek below diversion near Winthrop (12447387)	5.2	5.2	–	5.2	–	5.2	–	5.2	–	5.2	–
Andrews Creek (12447390)	3.6	3.6	–	3.6	–	3.6	–	5.6	58	3.6	–
Chewuch River above Cub Creek (12447600)	58	57	-2	59	–	56	-3	62	7	57	-2
Chewuch River at Winthrop (12448000)	88	85	-3	91	4	84	-4	92	5	78	-11

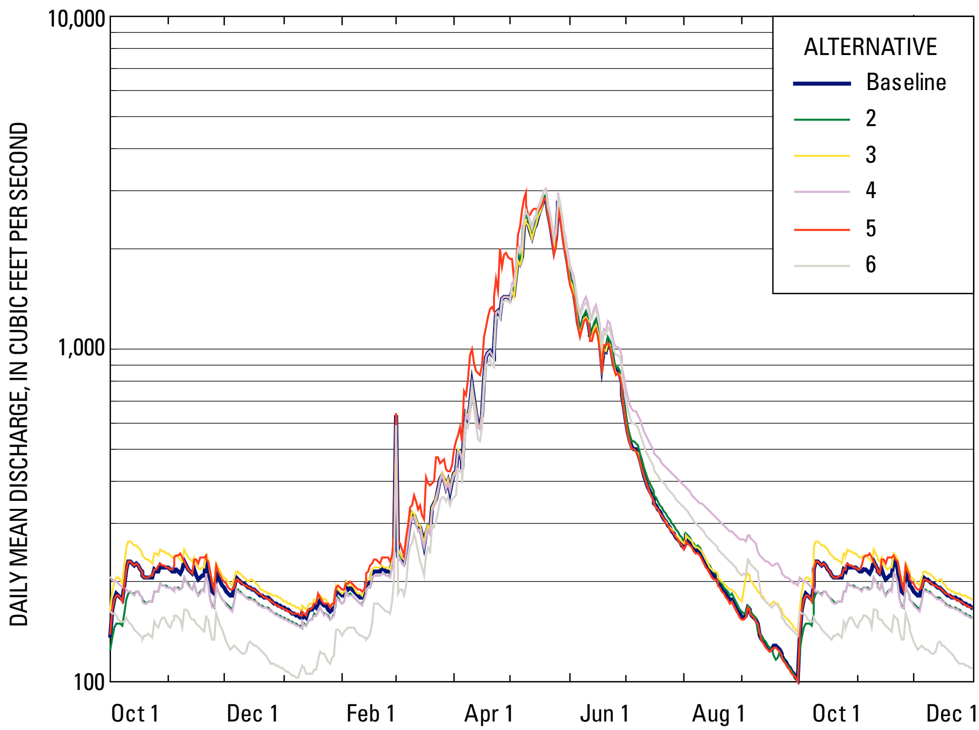


A. Twisp River near Twisp (USGS station 12448998)



B. Chewuch River at Winthrop (USGS Station 1244800)

Figure 2. 90-percent exceedence values for simulated daily streamflow at selected gaging stations for water years 1960–2001 for six water-management alternatives in the Methow River Basin.



C. Methow River near Pateros (USGS station 12449950)

Figure 2.—*Continued.*

Effects of Water-Management Alternatives on Low-Flow Conditions

The results of water-management alternatives for low-flow conditions were summarized in terms of monthly mean flows for September (table 3) and January (table 4) for all 12 stations and of daily streamflow that was exceeded in 90 percent of years in the Chewuch River near Winthrop, the Twisp River near Twisp, and the Methow River near Pateros (fig. 2). Lining irrigation canals (alternative 2) increased median September streamflow at most of the stations downstream of surface-water diversions (table 3, fig. 2). The increase in flows was a consequence of lower diversion rates, however it is not certain that surface-water diversions would be lower during September than under current conditions because seepage rates are already relatively low during September (Konrad and others, 2003). The largest increases in median September streamflow under alternative 2 were in the Chewuch River at Winthrop (27 percent), Early Winters Creek (23 percent), and the Twisp River near Twisp (17 percent).

Lining canals, however, had little effect on September flows in the Methow River near Pateros because of the small effect of lower diversions relative to flow near the mouth of the river, combined with the lack of ground-water discharge from irrigation-canal seepage. Lining canals had the greatest relative effect on September streamflow during dry years. The 90-percent exceedence value for September streamflow increased 77 percent in Early Winters Creek, 60 percent in the Chewuch River at Winthrop, and 40 percent in the Twisp River near Twisp.

Increasing diversions for additional aquifer recharge (alternative 3) increased median September streamflow at most of the stations downstream of surface-water diversions. The additional aquifer recharge increased ground-water discharge to rivers and streams. The increase in median September streamflow under alternative 3 was slightly more than the increase under alternative 2 (where there is no simulated seepage from irrigation canals) in the Methow River at Twisp and the Methow River near Pateros. With regard to dry years, the 90-percent exceedence value for September streamflow increased under alternative 3 at all stations downstream of

surface-water diversions except Early Winter Creek, Chewuch River above Cub Creek, and Wolf Creek. Lost River, Andrews Creek, and Twisp River above Newby Creek are above all diversions, so streamflow was unaffected under alternative 3 at these stations. The increase ranged from 2 percent in the Methow River at Goat Creek to 82 percent for the Chewuch River at Winthrop. The increase in the 90-percent exceedence value for September streamflow was greater under alternative 3 than alternative 2 for Methow River stations and the Chewuch River at Winthrop because recharge increased with diversions during early and mid-summer under alternative 3, but diversions in September were maintained at baseline levels.

Conversion to ground-water resources (alternative 4) generally increased September streamflow more than the other alternatives including natural streamflow (alternative 6) because some water applied to irrigate fields returned via ground-water flow to the rivers and streams. Median September streamflow increased by more than 23 to 69 percent at all stations below surface-water diversions except the Methow River above Goat Creek, where the increase was 5 percent. The increase was greater during low-flow years than during high-flow years, with all stations downstream of surface-water diversions showing at least a 47-percent increase in the 90-percent exceedence value for September streamflow, except the Methow River above Goat Creek, where the increase was 8 percent.

Forest-cover reduction (alternative 5) decreased median September streamflow by 4 percent in Andrews Creek, which was likely a result of earlier snowmelt and runoff in the year. Forest-cover changes in the Chewuch River Basin increased low flows during dry years: the 90-percent exceedence value for September streamflow increased by 25 percent at the Chewuch River above Cub Creek. A similar effect was not simulated for the Twisp River. Because the increase in annual flows was larger than the increase in low flows, much of the increase in annual runoff production due to forest-cover reduction would occur as a result of increased high flows during late spring and early summer in both the Chewuch and Twisp Rivers.

Natural streamflow (alternative 6) in September was higher than the baseline alternative at the stations downstream of surface-water diversions. Thus, under the baseline alternative, irrigation-canal seepage was less than the amount of water diverted from rivers in September.

The effects of all of the water-management alternatives on January flows are small, with the exception of changes in forest cover (alternative 5) and natural streamflow (alternative 6). Forest-cover conversion had the greatest effect at the stations located immediately downstream of the catchments with conversion (Twisp River above Newby and Andrews Creek), though it also affected streamflow at stations farther downstream. For example, the 90-percent exceedence value for January streamflow increased by 21 percent in the Twisp River near Twisp, 24 percent in Andrews Creek,7 percent in the Chewuch River above Cub Creek, and 6 percent in the Chewuch River at Winthrop. Natural streamflow (alternative 6) was lower in January than the baseline alternative at stations downstream of irrigated lands because of the elimination of irrigation-canal seepage.

Summary and Conclusions

The MMS precipitation-runoff model constructed for the Methow River Basin was used to simulate streamflow for the period from water years 1960 through 2001 under six alternatives representing current conditions, various water-management options, and natural flows. Lining irrigation canals (alternative 2) increased flows in the Chewuch, Twisp, and the Methow (upstream and at Twisp) Rivers during September because of lower diversion rates, but not in the Methow River near Pateros. Increasing diversions for aquifer recharge (alternative 3) increased streamflow from September into January, but reduced streamflow earlier in the summer at stations downstream of diversions. Conversion of surface-water diversions to ground-water wells (alternative 4) resulted in the largest increase in September streamflow of any alternative, but also marginally lower January flows (at most -8 percent in the 90-percent exceedence value). Forest-cover reduction (alternative 5) produced large increases in streamflow during high-flow periods and earlier onset of high flows and small increases in January streamflows. September streamflows were largely unaffected by alternative 5. Natural streamflow (alternative 6) was higher in September and lower in January than the baseline alternative.

The alternatives indicate that these types of water-management actions could cause substantial changes in the seasonal distribution of streamflow in the Methow River Basin. Late-summer streamflow could be increased in many reaches by (listed in descending order of effect): conversion of surface-water diversions to ground-water wells; lining irrigation canals; or artificial recharge through increased diversions earlier in the year. Winter flows could be increased by forest-cover reduction and, during dry years, artificial recharge through increased diversions.

References Cited

Ely, D.M., 2003, Precipitation-runoff simulations of current and natural streamflow conditions in the Methow River Basin, Washington: U.S. Geological Survey Water-Resources Investigations Report 03-4246, 35 p.

Konrad, C.P., Drost, B.W., and Wagner, R.J., 2003, Hydrogeology of the unconsolidated sediments, water quality, and ground-water/surface-water exchanges in the Methow River Basin, Okanogan County, Washington: U.S. Geological Survey Water-Resources Investigations Report 03-4244, 137 p.

Leavesley, G.H., Restrepo, P.J., Markstrom, S.L., Dixon, M., and Stannard, L.G., 1996, The modular modeling system (MMS): User's manual: U.S. Geological Survey Open-File Report 96-1511, 200 p.

Mastin, M.C., and Vaccaro, J.J., 2002, Documentation of Precipitation–Runoff Modeling System modules for the Modular Modeling System modified for the Watershed and River Systems Management Program: U.S. Geological Survey Open-File Report 02-362, 5 p.

National Marine Fisheries Service, 2000a, Endangered Species Act—Section 7: Biological opinion for the Wolf Creek irrigation ditch, Okanogan National Forest: WSB-98-050, 43 p.

National Marine Fisheries Service, 2000b, Endangered Species Act—Section 7: Biological opinion for the Early Winters and Willis irrigation ditches, Okanogan National Forest: WSB-98-058, 40 p.

National Marine Fisheries Service, 2000c, Endangered Species Act—Section 7: Biological Opinion for the Skyline Irrigation Ditch, Okanogan National Forest, WSB-98-061, 51 p.

Viger, R.J., Markstrom, S.L., and Leavesly, G.H., 1998. The GIS Weasel – An interface for the treatment of spatial information used in watershed modeling and water resources management, *in* Proceedings of First Federal Interagency Hydrologic Modeling Conference, April 19-23, 1998: Las Vegas, Nevada, v. II, chapter 7, p. 73-80.

Manuscript approved for publication, February 12, 2004

Prepared by the Publishing Group, U.S. Geological Survey,
Washington Water Science Center, Tacoma, Washington

USGS Publishing staff
Judith A. Wayenberg
Bill Gibbs
Linda S. Rogers

For more information concerning the research in this report, contact the
Washington Water Science Center Director,
U.S. Geological Survey, 1201 Pacific Avenue – Suite 600
Tacoma, Washington 98402
http://wa.water.usgs.gov

USGS

Konrad

Simulated Water-Management Alternatives Using the Modular Modeling System for the Methow River Basin, Washington

OFR 2004–1051

125 years of science for America

1879–2004